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The effects of relaxation on running efficiency in moderately trained individuals

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THE EFFECTS OF RELAXATION ON RUNNING EFFICIENCY IN MODERATELY TRAINED INDIVIDUALS

by

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ABSTRACT

This study investigated the effects of the initiation of active relaxation techniques during exercise on selected physiological and biomechanical measures. Moderately trained female runners (N=14) were divided into a control group and a relaxation group. Both groups underwent two, 25-minute runs at 75% of their measured maximal oxygen consumption (VO_{2max}). Physiological measures taken for each trial included heart rate (HR), ventilation (V_e), rating of perceived exertion (RPE), and oxygen consumption (VO_2). Each subject was also videotaped in each trial in order to measure various biomechanical factors including arm swing (AS), hip flexion (HF), and step length (SL). Both physiological and biomechanical measurements were taken every 5 minutes throughout the running bout with the two running bouts separated by a two-week intervention phase. The relaxation group was required to learn a modified autogenic training (AT)/progressive muscular relaxation (PMR) technique. The technique was incorporated from rest into their normal exercise habits over the two weeks. The control group was required to keep a log of their normal exercise habits, which had no expected effect on the physiological and biomechanical factors measured. This allowed both groups to have the same amount of contact with the examiner. Data were analyzed using a 2 x 2 x 5 ANOVA (group x trial x time) with repeated measures on the second and third factors. Interpretation of findings indicated that relaxation was unable to cause any change in the physiological measures taken although RPE was close to significance ($p = .053$). The normal drift associated with these physiological factors caused by prolonged exercise was unaffected by relaxation. The biomechanical factors of HF and SL were also unaffected by relaxation. However, the relaxation group was effectively able to lower their AS with relaxation, which decreased excessive muscular movement in the upper extremity. This may limit depletion of energy reserves thereby potentially improving the performance of the long distance runner. Previous investigations have been

split on the benefits of relaxation during exercise. The design used in the present study was similar to how a relaxation intervention would be used by a runner but significant results were not achieved. An intensive relaxation protocol lasting more than two weeks, and incorporating biofeedback during practice, may produce more positive results.

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In Partial Fulfillment of the Requirements for the Degree

Master of Science

by

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in Exercise and Sport Sciences at Ithaca College has been approved.

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DEDICATION

This thesis is dedicated to my parents, Donald and Sharon Reidy, for their undying support, love, and guidance throughout my life so far. They are such an inspiration in how I live my life and have shown me the dedication and hard work it takes to be successful.

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Chapter 1

INTRODUCTION

Recent research has pointed to running economy (RE) as a popular way of measuring differences in performance among long distance runners (Bailey & Pate, 1991; Daniels, 1985; Morgan & Craib, 1992). RE is defined as the steady state oxygen consumption at a given submaximal running velocity (Conley & Krahenbuhl, 1980). Those individuals who are more economical are able to conserve more energy allowing a lower oxygen cost of effort, potentially leading to an increase in running performance. Physiological, biomechanical, biochemical, and psychomotor factors contribute to the determination of overall running efficiency. There is no recognized perfect balance of these factors that describes optimal running efficiency but many theories exist as to improvements that may positively affect performance. The use of relaxation techniques is one means that can be suggested to improve economy and overall efficiency allowing for an increased performance in the long distance runner.

Relaxation techniques in sport have gained popularity over the past two decades. Many cognitive strategies have been developed in order to elicit the relaxation response including progressive muscle relaxation (PMR), autogenic training (AT), and Benson's relaxation response. The use of such relaxation procedures and cognitive structuring techniques cause a hypothalamic response called relaxation, leading to a decrease in sympathetic nervous system activity and decreases in metabolic activity (Benson, 1975). Elicitation of the relaxation response allows the body to work more efficiently and effectively in the task at hand. The mind can be seen as a catalyst in producing optimal performance of the body. By learning to use the performance enhancing qualities of the mind, involuntary physiological processes may be, to an extent, brought under conscious control.

This study will examine how RE and other physiological indices (heart rate (HR), rating of perceived exertion (RPE), biomechanics, O_2 consumption (VO_2), ventilation (V_e)) are affected by the elicitation of the relaxation response during exercise. With the use of relaxation to coordinate and improve efficiency, an improvement in RE is expected. This may be due to a decrease in metabolism or an increased efficiency of running biomechanics at a given workload.

Scope of the Problem

This study examined the influence of relaxation on running efficiency in moderately trained female runners (N=14). The subjects were randomly assigned to a control group (n=7) and a relaxation group (n=7). Physiological and biomechanical measurements were taken in order to determine if any improvement was caused by the implementation of relaxation during running.

Physiological factors included in this study were: HR, V_e, VO_2, and RPE. Each of these factors was measured every 5 min during a 25 min running bout. Biomechanical factors taken into consideration every 5 min included: SL, AS, and HF.

These data allowed the investigator to assess normal responses to long distance running and compare them to running when relaxation techniques are incorporated.

Statement of the Problem

The focus of the research was to determine the effects of relaxation intervention during running on physiological and biomechanical markers of running efficiency.

Hypothesis

The elicitation of the relaxation response during submaximal exercise will increase running performance as energy expenditure will be lower at a given workload when compared to control.

Delimitations

1) Subjects engaged in two weeks of modified PMR/AT relaxation training and did not have any prior experience with the relaxation techniques used. Other relaxation techniques were not examined in this study.

2) The subject sample was taken from the Ithaca community and consisted of moderately trained female runners.

3) Subjects were unaware of when they were being videotaped in order to allow for more natural measurement of AS, HF, and SL.

4) Physiological measurements utilized in the study included: HR, V_e, VO_2, and RPE.

5) An oversized treadmill was used in the study in order to cultivate a more normal gait by the subjects. Smaller treadmills may confine an individuals running gait. Treadmill accommodation runs were also utilized in order to allow gait to be as close to normal as possible.

6) Each trial in this investigation required subjects to run at 75% of VO_{2max} for 25 minutes. This duration and intensity was chosen to closely resemble a 3-mile cross country event as well as the average workout.

Limitations

1) Relaxation techniques may require more practice than the two weeks given to achieve maximum benefits. Original protocols of the relaxation techniques used in this study called for at least six months of training (Lichstein, 1988).

2) Data may not be generalizable to sedentary or elite runners due to the specific population studied. The study focused on runners who are moderately trained and did not account for the novice or elite runner. Also, the tests were conducted indoors on a treadmill. This type of setting may not reflect outdoor running on any surface.

3) Having cameras visible may have allowed subjects to be more aware of their running gait, affecting validity of the study.

4) The physiological measures taken in this study may not give a completely accurate look at the effects of relaxation on the sympathetic nervous system (SNS).

5) Running on a treadmill may affect normal gait when compared to running on land.

6) Findings may only be generalizable to similar work out durations. Longer and shorter distance events may have different responses to relaxation.

Definition of Terms

Running economy (RE)- Steady state oxygen consumption for a given submaximal running velocity (Caird, McKenzie, & Sleivert, 1999). Units of measurement are ml/kg/min

Efficiency- The relationship between work done and energy expended. While RE refers specifically to oxygen consumption, efficiency takes into account how well physiological, biomechanical, biochemical, psychomotor, and other factors are coordinated (Cavanagh & Kram, 1985).

Relaxation techniques- A variety of strategies which focus on reducing muscular tension and improving thought processes by elicitation of the relaxation response.

Moderately trained- A runner with at least one year running experience and a 10 km time between 38-45 minutes (Williams, Krahenbuhl, & Morgan, 1990).

Treadmill accommodation- An introductory running bout on a treadmill used to produce stable running gait and familiarize an individual with a treadmill.

Chapter 2

REVIEW OF LITERATURE

The review of literature for this study focused on the following areas: (a) relaxation, (b) running economy, (c) effects of mental strategies on RE, and (d) summary.

Relaxation

The relaxation response is an innate state found within all of us, and has been described as a hypothalamic response which is opposite the fight or flight response. Many relaxation techniques have evolved over the years to help try and decrease tension as well as increase performance. Luthe (1965) described the relaxation response as a state of "minimal stimulation where the low sensory input (diminished afferent stimulation) is coded by the reticular system and thalamus, which instructs the hypothalamus to mitigate ergotropic activity. Trophotropic functioning emerges by default as ergotropic signals subside." Ergotropic responses refer to those that emerge by stimulation of the sympathetic division of the autonomic nervous system. Trophotropic responses are those that are brought about by the parasympathetic division of the autonomic nervous system. Suppression of the sympathetic nervous system allows parasympathetic responses to be enhanced precipitating a relaxed state.

All relaxation techniques focus on tapping into this hypothalamic response. There are many techniques available today, the most popular include: autogenic training, meditation, yoga, progressive muscle relaxation, and Benson's relaxation technique. Some of these techniques have recently been developed while others have been around for centuries. No one technique has been proven more effective than the others as they all seem to be equally effective in eliciting the relaxation response at rest (Lichstein, 1988). Physiologic responses caused by relaxation include a decrease in heart rate, blood pressure, respiration rate, O_2 consumption, skeletal muscle activity as well as an increase in skin resistance and alpha brain waves (Solberg, Berglund, Engen, Ekeberg, and Loeb, 1996; Gieremek, Osiadlo, Rudzinska, and Nowotny, 1994). It could be speculated that such physiological changes would benefit the long distance runner by helping to conserve energy and increase economy.

Relaxation is a psychophysical response that allows an individual to bring physiological processes more under voluntary control and also allows the individual to become more aware of bodily processes. A useful distinction can be made between consciousness and awareness. Moshe Feldenkrais explained this distinction by stating "Awareness is consciousness together of what is happening within it or what is going on within ourselves while we are conscious" (Gauron, 1984). A primary goal of relaxation is to cultivate this internal focus and allow an individual to better regulate their physiological state. Everyone tries each day to elicit the relaxation response and relieve the stress brought upon us by everyday life. Internal awareness allows us to be aware of such factors as physiological processes, tension, and bodily sensations (as in the use of ratings of perceived exertion (RPE)). Each of us operates with a degree of limited body awareness as we become habit oriented and overlook efficiency as these habits cover our internal awareness. Relaxation allows the mind and body to become more cohesive, increasing the degree of body awareness, and allowing for increased efficiency.

As individuals attempt to increase their body awareness they often use the tool of biofeedback to guide them in their effort. Biofeedback is seen as a form of somatic performance enhancement, which "minimizes the role of cognitions in determining behavior while emphasizing objective situations and overt responses". Blumenstein, Bar-

Eli, and Tenenbaum (1995) examined the effects of biofeedback on the effectiveness of AT, imagery, and music training at rest as well as during the 100 meter dash. The subjects were randomly assigned to 5 groups including: control, placebo, music and imagery, AT and imagery training, and a combination of AT, music, and imagery training. Thirteen 20-minute treatment sessions were used for each subject, with the first seven consisting of just the normal assigned treatment. The final six sessions added biofeedback to the assigned treatment in an attempt to enhance the learning effect. Heart rate, EMG, galvanic skin response, and breathing frequency were measured before and after each session. Hundred meter dash times were measured before and after the 13 treatment sessions as well. Blumenstein et al. concluded that biofeedback is an effective means in allowing autogenic training to be more effective in decreasing the physiological factors measured. No significant difference was found in the 100 meter run which may be due to the activity demanding such a high intensity of effort. Relaxation may be beneficial with lower intensity, longer duration activities where energy may be conserved allowing enhanced performance. Although 13 relaxation sessions were enough to produce significant differences within the autogenic training group the length of relaxation training may not have been adequate in this study.

Training or practice plays an important role in the effectiveness of relaxation techniques (Gieremek et al., 1994; Boone & DeWeese, 1998; Caird, McKenzie, and Sleivert, 1999). Original versions of PMR and AT called for a minimum of six months of relaxation training. Newer abbreviated methods have shown significant effects with only one week of training (Lichstein, 1988). Some also believe that the longer the training period the better, as we never stop learning how to grasp the relaxation state (Benson, Dryer, and Hartley, 1978). The duration of training has a great effect on our ability to become more aware of how to trigger the relaxation response within us. Each of us may develop small or large differences in our thought processes used to bring about this response, and only through experience and practice are these processes discovered.

The bulk of relaxation research has been conducted with subjects at rest as opposed to during exercise. A study conducted by Gieremek et al. (1994) aimed at finding ways to attain deeper psychophysical relaxation at rest by employing conventional, monitored relaxation techniques in a single session. The study incorporated the conventional relax position, Schultz's AT, and two biofeedback techniques. HR, systolic blood pressure, diastolic blood pressure, and galvanic skin resistance measurements were taken every 5 minutes for 40 minutes to monitor changes. All three relaxation methods enhanced relaxation produced by the simple relax position.

Solberg et al., (1996) studied the effects of meditation on sharp shooting performance, an activity that relies on quieting the mind and lowering bodily metabolism to increase performance. Shooting is seen as a type of sport associated with sensitivity to tension and anxiety. Shooting accuracy improved with meditation in competitive situations but no significant difference was found under experimental test conditions. Relaxation markers including blood lactate, HR, and O_2 uptake were lower after meditation. A positive correlation was found between low tension and meditation according to subjective measures. The theory of an ideal or peak state of performance is supported by the significant relationship between good performance and low tension. Relaxation techniques use different approaches to help bring about these positive changes. The core concepts of the techniques utilized in this examination will be discussed in the following paragraphs.

AT was developed by Wolfgang Luthe and has been widely researched in Europe (Lichstein, 1988). Research is lacking in the United States in this area and translations of European studies are not easily acquired. Luthe believed that the psychophysiologic state during the practice of AT differs from normal psychophysiologic state. This autogenic relaxation state resides on the continuum between wakefulness and sleep. Schultz, another advocate of AT, described the autogenic state as a specific process involving changes of mental and bodily functions, which enables a person to step behind or dive under the usual pattern of those functions associated with conscious control in a waking state (Lichstein, 1988). AT consists of three components including: reduced afferent stimulation, repetitive phrases, and passive concentration (Lichstein, 1988). The repetitive phrases focus on six themes, which include: heaviness, warmth, cardiac regulation, respiration, abdominal warmth, and cooling of the forehead. By focusing these cognitions on various parts of the body the relaxation response is triggered. The passive attitude is the cornerstone of AT. This passive concentration allows relaxation to take place, stimulating trophotropic mechanisms, which reduce afferent stimulation within the nervous system. This produces an overriding of the sympathetic nervous system and allows prominence of parasympathetic response. While Luthe used a more cognitive approach in his AT, Jacobsen utilized a more physical approach in his method of relaxation.

Jacobson created another popular relaxation technique, in 1938, called PMR. PMR consists of sequentially tensing and releasing major skeletal muscles. By recognizing the difference between tensed and relaxed muscles the individual is able to open the gate to relaxation. PMR is based on the idea that the peripheral physiology and the brain affect each other as the level of arousal in one has an impact on the arousal of the other (Lichstein, 1988). Jacobson considered skeletal muscle as the most effective means of manipulating brain activity. Tension produced by the peripheral musculature allows the brain to recognize the feeling of tension and allow the individual to more effectively focus on ridding the body of it.

Herbert Benson (1975) also had a large impact on the development and investigation of relaxation techniques. Benson cited four essential components to induce the relaxation response. First, relaxation is optimal when done in a quiet environment with as few distractions as possible. Second, a mental device must be employed, allowing the mind to shift from externally oriented thought; and it should be a constant stimulus such as a sound, word, or fixed gazing. Benson recommended paying attention to the normal pattern of breathing to prevent the mind from wandering. Third, relaxation is most effective when the individual is in a comfortable position with the lowest possible muscular tension. Fourth and most importantly, a passive attitude should be undertaken. Distracting thoughts should be disregarded and the individual should not be concerned with how well they are performing the technique. If distracting thoughts surface the subject should return smoothly to the mental device. These four components are the basis to most relaxation techniques that have been developed. While all of these components cannot be incorporated into a running situation, the important concepts can. For this reason relaxation training may take longer to be effective in these situations, as the individual needs to slowly incorporate the technique into their exercise.

Of the techniques presented, not one has proven to be more effective than the others. A combination of techniques can be used as an effective approach to achieving relaxation. As long as the underlying concepts to the techniques are adhered to, freedom to experiment with the techniques is possible. How such a relaxation technique can affect exercise performance needs to be explored more completely.

Running Economy

As mentioned earlier RE can be defined as steady state oxygen consumption for a given submaximal running velocity. RE is a measure of efficiency or how effectively energy is utilized by the body. A desirable economy minimizes energy usage and optimizes performance. Minimizing the usage of both external and internal energy is desirable to improve RE. External energy is that energy used to overcome external resistance such as gravity, friction, force or wind resistance while internal energy is energy used in the production of external energy (Bailey & Pate, 1991). External energy is affected by such factors as age, segmental mass distribution, stride length, and other biomechanical variables and can be looked at as muscle energy usage. Internal energy, on the other hand, is associated with the oxygen delivery to the working muscles, thermoregulation, and substrate metabolism. The overall goal of minimizing internal energy is to minimize the amount of ATP needed by the whole body to support production of ATP in the working muscles. Internal energy is affected by heart rate, ventilation, temperature, training status, fatigue, and mood state. RE could feasibly be improved by reducing the demand for external energy, internal energy, or a combination of both.

Fiber type composition also plays a role in affecting RE values. Slow twitch fibers have been described as more efficient than fast twitch fibers (McArdle, Katch, & Katch, 1994). Slow twitch fibers are adapted for prolonged work and are recruited more for aerobic activities. In contrast, fast twitch fibers are recruited in more anaerobic activities and produce a more forceful but less efficient contraction. For these reasons slow twitch fibers are more desirable for the long distance runner due to their increased efficiency. Differences observed in muscle economy between individuals may also lie in differences in the ability to store and reuse elastic energy. The different coupling times of fast twitch and slow twitch fibers may affect this utilization of elastic energy. Slow twitch fibers are known to have a longer coupling time allowing easier retention of elastic energy without detachment of the actin-myosin crossbridge. Bosco et al. (1987) found that those with a higher percentage of fast twitch fibers present in the vastus lateralis had a higher net energetic cost of running. This suggests that for long distances slow twitch fibers are more desirable due to their increased efficiency of work.

Morgan and Craib (1992) examined the literature discussing the physiological aspects of RE. They found that interindividual variation in economy has been linked to differences in HR and V_e. Changes in V_e caused by a reduced breathing frequency and an increased tidal volume have been suggested by Bailey and Pate (1991) to decrease VO_2. They believed that by reducing the internal energy demands of an individual such as reducing heart rate, lowering ventilation, and increasing the percentage of carbohydrates oxidized for energy metabolism may effectively improve running economy. The use of relaxation may be one means of achieving such goals. These authors concluded that despite growing interest in RE, many physiological issues lack consensus or remain to be explored in greater detail. Future research should be focused toward explaining group differences in economy through the use of a broad range of interdisciplinary research tools. In order for running economy to be effectively examined knowledge of day to day changes must be examined.

Williams, Krahenbuhl, and Morgan (1991) did exactly this when they investigated daily variation in RE of moderately trained male runners. Williams et al. defined a moderately trained runner as a runner who had engaged in a systematic training program of endurance running for at least one year and had a current 10 km time between 38 and 45 min. Ten males between the ages of 20-34 years were examined in the study. The subjects were asked to maintain their normal training programs, adhere to their regular diets, and were monitored through the use of a daily training log. Each subject performed a pre and post VO_{2max} treadmill test to account for any training effects that may have occurred as well as submaximal treadmill accommodation runs at 50%, 60%, and 70% of VO_{2max} to ensure establishment of stable gait mechanics. Each accommodation run session consisted of ten minute bouts of running at each of the three intensities separated by ten minutes of rest. Twenty RE tests were performed five times a week for four weeks. In each of these sessions the subjects ran for six minutes at each intensity and VO_2 was collected. The results reflected that in conditions where treadmill accommodation, time of day, footwear, and test equipment are controlled, RE seems to be a stable physiological measure in moderately trained male runners.

Morgan, Martin, & Krahenbuhl (1991) expanded on Williams et al. findings by examining the variability of RE as well as mechanics among trained male runners. Morgan conducted two separate studies, which examined RE and biomechanics. The RE data were analyzed to quantify variability in and reliability of, RE and biomechanics, in trained male runners who performed duplicate submaximal runs under controlled testing conditions. These duplicate submaximal runs consisted of treadmill running at 3.33 $m \cdot s^{-1}$ for 8-10 minutes with gas collection and biomechanical measures. Biomechanical variables measured included step length, stance time, swing time, shank angle at heel strike, plantar flexion angle at toe off, and vertical deviation of body mass among others. When expressed as a percentage of VO_{2max}, RE was found to have a day to day variation of 1.86%. Data from both investigations revealed that stride to stride and day to day variation in the running pattern was minimal. From a total of 22 variables submitted for analysis, only three were found to have significant statistical differences. Peak resultant velocity of the ankle joint (study 1), step length (study 2) and swing time (study 2) were slightly higher in the second study. Step length was also found to differ 9% between individuals, which may be due to anatomical differences. Their conclusion was that a stable measure of RE can be obtained in a single data collection session involving trained, nonelite male runners if the testing environment is controlled to minimize nonbiological variability. Therefore, according to Williams et al. and Morgan et al. findings, RE can be reliably measured when the proper factors are controlled. Differences, however, are present in similarly trained individuals.

Daniels' (1985) physiological examination of RE referred to efficiency as the relationship between work done and energy expended. In his review he addressed both interindividual and intraindividual factors associated with RE. Daniels speculated that there seems to be a certain threshold of training which affects RE. Literature he examined is split on the issue of an increase in VO_2 being attributed to training. Morgan and Craib's review (1992) on RE found the literature to strongly support better RE in long distance runners when compared to middle distance runners and sprinters. Also, individuals who specialize in shorter distance events have a superior RE at faster speeds while long distance specialists tend to be more economical at slower speeds. This shows that specificity of training plays a large role in determining RE. Daniels associated six factors contributing to intraindividual differences in RE including: age, air or wind resistance, body temperature, stride length, additional weight, and training level. In conclusion, differences can and do exist between and within individuals regarding the amount of energy expended at any given submaximal running speed. The reasons for these differences and how to best bring about desirable changes in RE are not clear. By eliminating unwanted or counter-productive muscular movement Daniels believed efficiency is maximized. Any motion that increases unnecessary biomechanics can be detrimental to RE measures.

In 1991, Bailey & Messier examined variation in stride length and RE in male novice runners subsequent to a seven week training program. They imposed a training protocol of 22 running bouts of 20 min at 60% of VO_{2max} on 22 male novice runners divided into a constant stride length group and a freely chosen stride length group. The basis of their investigation revolved around the idea that alterations in stride length have been found to increase RE as well as lower rates of perceived exertion in experience runners. Bailey and Messier concluded that stride length variations had no significant effect on RE. Only during the fourth week of training were the two groups statistically different in percentage of stride length change. Their conclusion was that stride lengths of novice runners remain variable following seven weeks of treadmill running. They also speculated that experienced runners, in contrast to novice runners, obtain a near optimal stride length by either altering their stride length and stride frequency in an effort to minimize RPE or these changes become physiologically optimal through training.

In contrast, Cavanagh and Williams (1982) examined the effect of stride length variation on VO_2 using more experienced runners. Using a metronome to signal time of foot strike at a known treadmill speed, Cavanagh and Williams were able to change step length of an individual. VO_2 was measured for seven stride lengths for each individual, including a freely chosen stride length. In general the freely chosen stride length deviated little, with an average deviation of .2 ml·kg^{-1}· min^{-1}, from the optimally predicted stride length. Two possible mechanisms were cited as possible causes of this phenomenon. First, the subjects may have developed this chosen step length based on RPE. Ratings of perceived exertion have been shown to be linearly related to work intensity and physiological measures. A second possibility is that this close to optimal chosen step length may have adapted through training to the individuals personal running style. In other words, their physiological mechanisms have adapted to be optimal for their running gate. Exactly what effect step length or stride length have on an individuals energy usage is an area where more research needs to be done. The present investigation approaches this problem from a different perspective by seeing how relaxation impacts energy usage and step length rather than how changes in step length affect energy usage.

Effects of Mental Strategies on Running Economy

RE should be optimal when there is the proper balance of physiological and psychological processes. The elicitation of the relaxation response decreases arousal, subsequently decreasing sympathetic activity. Factors found to affect RE include: training status (Conley & Krahenbuhl, 1980), treadmill accommodation (Williams et al., 1991), fatigue, and psychological state (Crews, 1992). Caird, McKenzie, & Sleivert (1999) examined the effectiveness of biofeedback and relaxation techniques on the RE of seven sub-elite long distance runners. Subjects participated in a pretest where RE, lactate threshold, stretch shortening cycle efficiency, and peak running velocity were measured. This pretest was followed by a control phase of six weeks where the subjects continued with their present training. Each subject underwent a post control phase test in order to determine if physiological measures were stable. If stable, the subjects moved on to a six week intervention phase where PMR and centering (a cognitive relaxation protocol) techniques were learned. The posttest followed, measuring the same variables as the pretest while relaxation was done before (i.e., PMR) and during (i.e., centering) exercise. Caird et al. found that a combined biofeedback and relaxation treatment improved RE. These findings were related to a decreased rate of V_e without a decrease in HR. The mechanism for a decrease in RE without a subsequent decrease in HR is not understood. Although this research was thorough and controlled for many factors, it only focused on the initial ten minutes of exercise and therefore was not generalizable to long distance running. They only looked at initial steady state measures instead of changes over the duration of a running bout which would be desirable in long distance runners.

Boone & Deweese (1998) examined the effect of PMR on RE. After eight, 30 minute relaxation sessions where HR, systolic blood pressure (SBP), and rate pressure product (RPP) were monitored, subjects participated in a 30 min, three phase exercise bout. The first ten minutes consisted of just normal running with no relaxation, followed by ten minutes of exercise where the relaxation response was initiated, and the final ten minutes was another control phase with no relaxation. Significant differences were found in frequency of breaths (F_b), V_e, SBP, RPP while no significant differences were found in VO_2, respiratory exchange ratio, and HR. The results of the study suggest that F_b and V_e are not fixed at a constant work intensity. F_b and V_e significantly decreased by 10% and 4%, respectively, and increased following the relaxation phase. SBP also significantly decreased by 6% causing a subsequent decrease in RPP values allowing the performer to better tolerate the central demand of exercise and increase performance. Due to the difficulty of performing PMR during exercise, it should have been practiced during exercise rather than at rest.

In 1992, Hatfield, Spalding, Mahon, Slater, Brody and Vaccaro examined the effects of biofeedback versus psychological distraction on physiological indices of running just below ventilatory threshold. The physiological cost of negotiating a workload was hypothesized to be lowered by using such a behavioral manipulation. In their study, 12 trained males completed a 36 min run (average of 71% VO_{2max}) which was divided into three 12 min phases including a feedback phase, distraction phase, and control phase. The feedback phase consisted of V_e measures provided for the subjects. This allowed them to be more aware of their breathing and focus on lowering it. The distraction phase consisted of a timing task that required anticipatory judgment. Subjects were required to press a button they held throughout the exercise that was connected to a series of lights that flashed one after the other. The subjects were to press the button when the third or middle light was lit. The distraction phase helped to focus the subject's attention away from the stress of running. The control phase consisted of just normal running the subjects would normally engage in when they exercise. Values obtained during exercise included V_e, VO_2, pressure of end tidal O_2 ($PETO_2$), pressure of end tidal CO_2 ($PETCO_2$), and respiratory rate (RR). The feedback phase was found to lower these variables the most (except $PETCO_2$ which increased). The distraction phase also lowered the dependent variables. The two techniques were successful in lowering desirable indices when compared to the control. Subjects were able to maintain a similar VO_2 level across all three conditions while breathing a reduced volume of air. This was probably due to a greater O_2 extraction from the inspired air. This assumption was derived from $PETO_2$ to $PETCO_2$ differences. RPE was also found to be lower in the feedback and distraction phases when compared to controls. In conclusion, although a change was not observed in VO_2, the treatment phases seemed to have an effect on lowering V_e/VO_2. These findings may decrease energy demand and increase performance in the long distance runner.

Gervino and Veazey (1984) examined the physiologic effects of Benson's relaxation response, a form of PMR, during submaximal aerobic exercise performed on a bicycle ergometer. The study called for home practice of the Benson relaxation technique. The subjects exercised at steady state and were monitored in four, eight-minute stages. The sequence proceeded as follows: control phase, relaxation phase, control phase, relaxation phase. A decrease in VO_2, RER, SBP, RPP, and V_e was found while significant changes were not found in HR values. The authors believe that the findings generated by this study may prove beneficial for those with coronary artery disease. The elicitation of the relaxation response may delay the onset of ischemia by decreasing the stress placed on the heart. This may also result in an improved exercise tolerance for such individuals.

Mental strategies include those that can be divided into associative and dissociative strategies. Associative strategies are defined as those that attend to bodily responses, while dissociative strategies are those attending to thoughts other than bodily responses. Elite runners have traditionally been characterized to use more associative strategies leading to the assumption that these associative strategies develop with experience. According to Crews (1992), a definite relationship exists between exercise and these types of emotions or affect. Affect is defined as an emotion or feeling related to an idea or object. The use of psychological strategies and biofeedback can be very beneficial in affecting RE by allowing greater awareness of physiological responses. These types of strategies can effectively alter affect and promote increased efficiency. Of the 30 studies examined in Crews' review, strategies used to alter affect consistently improved performance significantly.

Central command has been hypothesized by Perski, Tzankoff, & Engel (1985) to control motor and cardiovascular responses separately during dynamic exercise. Their study focused on applying this hypothesis to more severe work rates when motor commands are less likely to be dissociated from the cardiovascular control centers. Subjects were given feedback during exercise in order to learn to better voluntarily control their SBP, VO_2, and HR. Epinephrine (E), and norepinephrine (NE) were measured at 65% of maximal heart rate following four training phases. HR decreased by an average of 22% in the treatment group. There was a decrease in RPP but this was mostly due to the change in HR because there was no significant change in SBP found. Although E was found to increase, both E and NE both had no statistically significant change. This rise in E should have had an excitatory impact on the heart if any, not the decrease that was found. HR attenuation during exercise seemed to be mediated primarily by the vagal route of the autonomic nervous system. In conclusion, the findings presented by Perski et al. showed that even under conditions of moderate to heavy exercise there can be an input from the central nervous system that alters the pattern of cardiovascular adjustments.

Summary

An important aspect of long distance running is the ability to stay relaxed and utilize energy as efficiently as possible. The ability to accomplish this task will allow the long distance runner to improve performance. Implementation of a relaxation technique is one way of helping the long distance runner stay relaxed and work towards this goal. Several relaxation techniques exist, but none are specifically designed to be implemented during exercise. Although exercise is used as a means to increase metabolism, research examining relaxation may be beneficial for the competitive runner as a means to become more efficient.

The previous paragraphs have given an in depth review of literature surrounding the effects of mental strategies effects on running efficiency. The literature on this topic appears to be incomplete and conflicting at best. How exactly relaxation during exercise effects running efficiency is still not completely understood.

Chapter 3

METHODS

Overview

The purpose of this investigation was to examine the effects of performing relaxation during exercise on running efficiency in moderately trained individuals. Subjects were divided into a relaxation group and a control group, with each group completing two twenty-five minute runs at 75% of their measured VO_{2max}. During each running bout, physiological measurements including VO_2, HR, V_e, and RPE were measured. In addition, biomechanical factors examined were arm swing (AS), hip flexion (HF), and step length (SL). Each of these measurements was taken at five minute intervals throughout the exercise test. This protocol allowed determination of any changes in factors that affect RE that were altered by the relaxation response.

The relaxation group subjects underwent two weeks of relaxation training following the pretest in order to get an understanding of the modified PMR/AT technique utilized in the study. The technique was practiced twenty minutes a day, first with the subject resting and then eventually incorporated into exercise. The control group monitored their exercise habits in the two weeks between trial I and trial II through the use of an exercise log. These individuals were told to adhere to their regular training programs.

Selection of Subjects

Subjects were moderately trained female runners, ages 18-40 years, recruited from Ithaca College and the surrounding community. See Appendix A for recruitment flyer information. All subjects signed an informed consent form that gave permission to videotape the individual (Appendix B).

A brief questionnaire (Appendix C) was administered to each subject focusing on previous relaxation experience, present fitness level, and general health. Those who had previous relaxation experience were included in the study if this experience was not in either PMR or AT and if their training had not been too extensive. Too much exposure to one technique may carry over into the effectiveness of other techniques, affecting results. This prevented the sample from being biased toward enhanced relaxation effects. Most of the population has had some exposure to relaxation techniques as each of us search everyday for ways to relax. This examination is more focused on initial impacts of relaxation. The subjects were asked about any medical illnesses or medication they were taking to account for any unforeseen factors that may affect the outcome of the study.

Subjects in this study were moderately trained individuals, who have been running at least three times a week for the past year or more. This level of experience was thought to allow for a more stable running gait pattern as well as better adaptation to optimal biomechanics following relaxation. These athletes have usually adapted biomechanics to become as efficient as possible.

Treadmill Accommodation

Each subject participated in a treadmill accommodation run. This has been suggested by a number of studies to stabilize gait and allow measures to become more reliable (Bailey & Messier, 1991, Blumenstein et al., 1995, Boone & DeWeese, 1998). These studies recommend an accommodation period of 20-60 min. The accommodationrun in this study consisted of 20 min of running at 75% of age predicted maximal HR. No physiological measures were taken during the accommodation run as the subjects became comfortable with the oversized treadmill that was used during the testing.

Maximal Oxygen Consumption Test

Each subject completed a VO_{2max} test in order to determine the intensity (treadmill speed) needed to sustain 75% of VO_{2max} and 75% max HR throughout the testing phases. Subjects began the testing on a 0% grade running at a self-selected, comfortable but brisk pace. Treadmill grade was then increased 2% every three minutes until volitional exhaustion occurred. Open circuit spirometry using a metabolic cart (ParvoMedics-TrueMax 2400; Salt Lake City, UT) was used to collect expired gases of the subjects during the graded exercise test. The final minute of each three-minute stage was averaged to determine the subject's VO_2. HR was also monitored using HR monitors (Sensor Dynamics, Inc.; Fremont, CA) in order to establish maximal HR. HR as well as RPE was recorded at the end of each stage.

Trial I

Subjects ran for 25 minutes at 75% of measured VO_{2max} on an oversized treadmill (FitNex; Fallbrook, CA) in order to allow for the most natural gait mechanics as possible. Physiological measures including HR, VO_2, V_e, and RPE were monitored. The exercise bout was divided into 5-minute stages with the average of the final minute of each stage used for measuring VO_2 and V_e. RPE and HR were taken at the end of each five-minute stage as well.

Recording of gait for biomechanical analysis was accomplished with a single camera system (MotionAnalysis; Santa Rosa, CA) set at 60 frames per second (fps) and with filming taking place for the final 15 seconds of the five, 5-min stages. Biomechanical factors taken into account included: SL, HF, and AS. A total of 7 reflective markers were placed on the subject for video analysis. Markers were placed on the acromion process of the shoulder, lateral epicondyle of the humerus, styloid process of the wrist, greater trochanter of the hip, lateral joint line of the knee, distal to the lateral malleolus of the left ankle and over the 5th metatarso-phalangeal joint of the right foot. The camera was placed perpendicular to the treadmill at a distance of approximately 15 feet. AS motion was determined by taking overall movement of the elbow marker in degrees. HF measurements were determined by the change in angle between the shoulder, hip, and knee and measured in degrees. Distance between the two-foot markers was taken at the largest point of separation for SL measurements and was expressed in cm.

Relaxation Training

Relaxation training was administered for a two-week period with the first week unsupervised and the second week partially supervised. Supervised training improves learning of the relaxation response (Boone & DeWeese, 1998). Following trial I the relaxation technique was explained and any questions were answered.

Week 1-The subject practiced a modified combination of the PMR and AT at rest, as described by Lichstein (1988) (See Appendix D). An instructional session and written explanation was given about these methods before the subjects are sent home for a week to practice the techniques. The subjects were told to practice 20 minutes a day, preferably before they went to sleep. A calendar was also given to the subjects for them to put in a noticeable place as a reminder to adhere to the protocol.

Week 2- Unsupervised training continued through week two. In addition, each subject participated in one 20 minute supervised relaxation training session during exercise at the beginning of week 2. This session allowed them to get a feel for the technique while running. Subjects were also encouraged to practice the technique during exercise on their own. Biofeedback was given to the subjects during the supervised sessions in order to help them to elicit relaxation. This was accomplished by allowing them to see a HR monitor as well as their VO_2 and V_e values. This method was used as a means to help them more easily elicit the relaxation response by giving them subjective measurements to focus on.

Control Group

The control group was required to keep an exercise log describing their exercise habits over the two weeks between trial I and trial II. They were instructed not to change their training habits and write down what they did and how long they did it. These individuals had the same contact with the investigator as the relaxation group as they were also required to return at the beginning of week two for a 20 minute run. As established earlier, RE is a stable measurement and should therefore have not changed in the control subjects.

Trial II

Treatment Group

Trial II was the same as the trial I with subjects running at 75% of VO_{2max} and the same physiological and biomechanical measures taken. The first five minutes consisted of normal running in order to achieve steady state. Beginning at minute 5, the relaxation subjects began to elicit the relaxation response as described in Appendix D. The PMR section of the technique took a maximum of two minutes with the subject focusing on the AT section of the relaxation technique throughout the duration of exercise. At minute 15, PMR section was repeated and the AT portion continued again throughout the exercise bout. Trial II was performed at the same time of day and in the same footwear as the trial I so as to make economy measures as reliable as possible.

Data Analysis

Data were statistically analyzed using a 2 X 2 X 5 ANOVA (group X trial X time) with repeated measures on the second and third factors in order to determine any significant difference in the physiological measurements (HR, RPE, V_e, and VO_2). Biomechanics were analyzed in order to see if possible coordination improvements affected RE. The AS, HF, and SL data were obtained through the use of the Motion Analysis software (Motion Analysis Corp., Santa Rosa, CA) and were also analyzed with the 2 X 2 X 5 ANOVA. Tukey's post-hoc analysis was used to determine specific significant differences between the dependent variables measured.

Chapter 4

RESULTS

The results of the investigation on the effects of relaxation on running efficiency in moderately trained individuals are presented in this chapter. The chapter is divided into the following sections: (a) heart rate analysis and descriptive statistics, (b) ventilation analysis and descriptive statistics, (c) RPE analysis and descriptive statistics, (d) oxygen consumption analysis and descriptive statistics, (e) arm swing analysis and descriptive statistics, (f) hip flexion analysis and descriptive statistics, (g) step length analysis and descriptive statistics, and (h) summary.

Heart Rate Analysis and Descriptive Statistics

The summary of the 2 x 2 x 5 ANOVA for HR can be found in Table 1. No significance was found for the trial x time x group interaction (F (4,48) = .67 p > .05). The three, two-way interactions including trial x group (F (1,12) = 3.18 p > .05), time x group (F (4,48) = .51 p > .05), and trial x time (F (4,48) = .24 p > .05) were also found to be statistically nonsignificant. Significance was found, however, in main effect for time (F (4,48) = 22.83 p < .05). The Tukey post-hoc analysis revealed that HR at min 10, 15, 20, and 25 was significantly greater than min 5 and HR at min 25 was significantly greater than min 10 for all subjects (Table 2). Relaxation had no effect on altering the normal HR drift associated with prolonged exercise, as each group had a similar progression during both trials. Main effects for trial (F (1,12) = 1.45 p > .05) and group (F (1,12) = .05 p > .05) were not significant. Overall, the HR measures for the subjects were unaffected by the introduction of relaxation (Figure 1). Means (M), standard

Table 1

HR ANOVA summary table

Source	SS	df	MS	F	p
Group	115.21	1	115.21	.05	.84
Sw/Group	30634.34	12	2552.86		
Trial	61.78	1	61.78	1.45	.31
Trial x Group	171.61	1	171.61	3.18	.10
Error (Trial)	646.91	12	53.91		
Time	2405.69	4	601.42	22.83	.00*
Time x Group	53.40	4	13.35	.51	.73
Error (Time)	1264.51	48	26.34		
Trial x Time	16.54	4	4.14	.24	.91
Trial x Time x Group	45.86	4	11.46	.67	.62
Residual	822.80	48	17.14		

*Denotes significance found at the .05 level.

Table 2

Tukey post-hoc analysis for HR

Means		153.64	159.86	162.00	163.36	165.89
	Time	5	10	15	20	25
153.64	5	-	-	-	-	-
159.86	10	6.22*	-	-	-	-
162.00	15	8.36*	2.14	-	-	-
163.36	20	9.72*	3.50	1.36	-	-
165.89	25	12.25*	6.03*	3.89	2.53	-

*Denotes significance with a critical difference of 4.62.

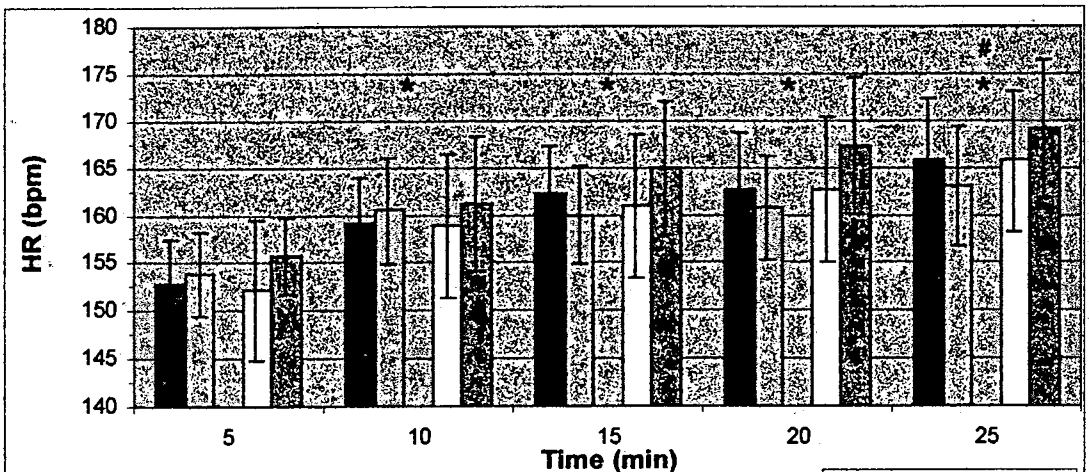

Figure 1. Comparison of HR +/- SEM changes between relaxation and control groups. * = HR significantly greater than at min 5. # = HR significantly greater than min 10.

deviations (SD), and standard error of the means (SEM) were calculated for HR at minutes 5, 10, 15, 20, and 25 for each subject that participated and can be seen in Table 3. The progression of HR for the relaxation group in trial II appears to be slightly different from the control group, however no significant interaction was found.

Ventilation Analysis and Descriptive Statistics

The ANOVA for V_e revealed no three-way interaction for trial x time x group (F (4,48) = 1.32 $p > .05$) as can be seen in the ANOVA summary in Table 4. The two-way interaction of trial x group was found to be significant (F (1,12) = 7.11 $p < .05$). Tukey post-hoc analysis revealed that the control group had significantly higher values for both trials than the relaxation group (Table 5). Although the two groups were initially significantly different, there was no significant change from trial I to trial II for either group (Figure 2). The other two-way interactions of time x group (F (4,48) = .33 $p > .05$) and trial x time (F (4,48) = .50 $p > .05$) were not significant. As with HR, the time main effect for V_e was found to be significant (F (4,48) = 21.21 $p < .05$). Again, the expected physiological drift with prolonged exercise caused a significant increase in min 15, 20, and 25 when compared to the initial steady state value at min 5 (Table 6). No other main effects were found to be significant, including group (F (1,12) = 3.00 $p > .05$) and trial (F (1,12) = .11 $p > .05$). Descriptive statistics for V_e data can be found in Table 7.

Table 3

Heart rate descriptive data

	Trial I			Trial II		
Group	Mean	SD	SEM	Mean	SD	SEM
Relaxation (N=7)						
Minute 5	152.86	11.87	4.49	153.86	11.48	4.34
Minute 10	159.00	12.87	4.86	160.43	14.75	5.58
Minute 15	162.14	13.47	5.09	160.00	13.48	5.09
Minute 20	162.71	15.67	5.92	160.71	14.38	5.44
Minute 25	165.71	17.16	6.49	163.00	16.52	6.25
Control (N=7)						
Minute 5	152.14	19.22	7.27	155.71	10.34	3.91
Minute 10	158.86	20.01	7.56	161.14	18.84	7.12
Minute 15	161.00	20.03	7.57	164.86	18.89	7.14
Minute 20	162.71	20.01	7.56	167.29	18.99	7.18
Minute 25	165.71	19.70	7.45	169.14	19.57	7.40

Note. Values are in beats per minute (bpm).

Table 4

V_e ANOVA summary table

Source	SS	df	MS	F	p
Group	2410.24	1	2410.24	3.00	.11
Sw/Group	9624.32	12	802.03		
Trial	1.43	1	1.43	.11	.74
Trial x Group	90.71	1	90.71	7.11	.02*
Error (Trial)	153.17	12	12.76		
Time	520.25	4	130.06	21.21	.00*
Time x Group	7.99	4	1.20	.33	.86
Error (Time)	294.33	48	6.13		
Trial x Time	4.51	4	1.13	.50	.73
Trial x Time x Group	11.87	4	2.97	1.32	.28
Residual	107.83	48	2.25		

*Denotes significance found at the .05 level.

Table 5

Tukey post-hoc analysis for V_e trial by group interaction

Means		47.51	46.11	54.21	56.02
	Trial	IR	IIR	IC	IIC
47.51	IR	-	-	-	-
46.11	IIR	1.4	-	-	-
54.21	IC	6.70*	-	-	-
56.02	IIC	-	9.91*	1.81	-

Note. R= relaxation group; C= control group

*Denotes significance with a critical difference of 2.52.

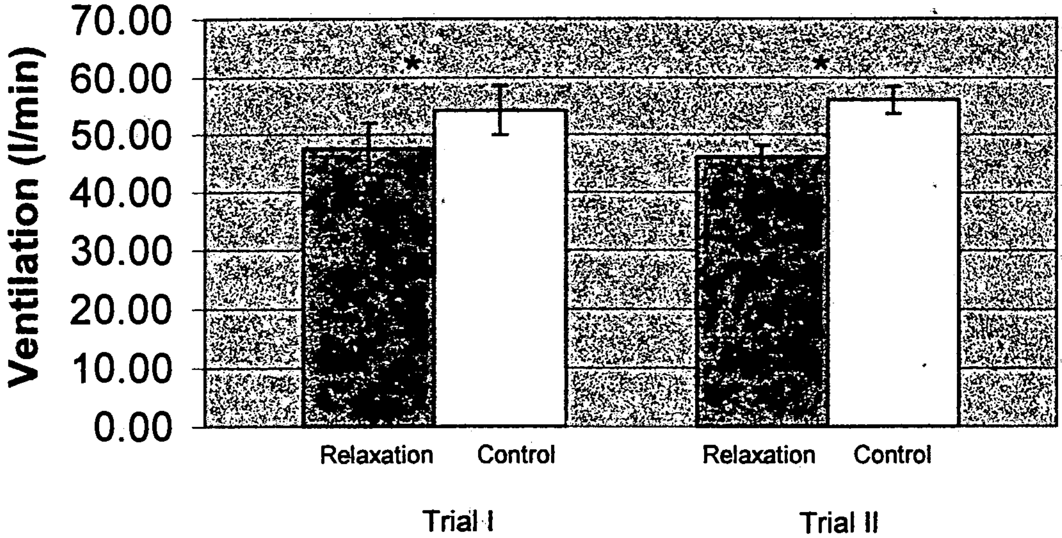

Figure 2. Trial comparison of ventilation means +/- SEM for the relaxation and control groups. * = control significantly greater at each trial.

Table 6

Tukey post-hoc analysis for V_e time main effect

Means		47.85	49.91	51.31	52.47	53.28
	Time	5	10	15	20	25
47.85	5	-	-	-	-	-
49.91	10	2.06	-	-	-	-
51.31	15	3.46*	1.40	-	-	-
52.47	20	4.62*	2.56*	1.16	-	-
53.28	25	5.43*	3.37*	1.97	.81	-

*Denotes significance with a critical difference of 2.07.

Table 7

V_e descriptive data

Group	Trial I Mean	Trial I SD	Trial I SEM	Trial II Mean	Trial II SD	Trial II SEM
Relaxation (N=7)						
Minute 5	44.63	11.19	4.23	43.53	11.25	4.25
Minute 10	47.16	12.36	4.67	44.29	11.03	4.17
Minute 15	46.87	11.80	4.46	46.80	11.43	4.32
Minute 20	49.12	11.33	4.28	47.23	12.12	4.58
Minute 25	49.79	12.34	4.66	48.69	11.59	4.38
Control (N=7)						
Minute 5	50.79	3.06	1.16	52.43	4.98	1.88
Minute 10	53.06	4.72	1.79	55.12	6.93	2.62
Minute 15	55.04	4.91	1.86	56.52	5.76	2.18
Minute 20	55.68	6.34	2.38	57.84	6.51	2.46
Minute 25	56.46	6.80	2.57	58.17	6.93	2.62

Note. Values are in l/min.

RPE Analysis and Descriptive Statistics

The three-way interaction of trial x time x group was not found to be significant (F (4,48) = .24 $p > .05$) for RPE. Also, no significance was found in the two-way interactions tested, trial x group (F (1,12) = 4.60 $p > .05$), time x group (F (4,48) = .82 $p > .05$), and trial x time (F (4,48) = 1.06 $p > .05$) (Table 8). Trial x group approached statistical significance with p = .053. A significant change in V_e would normally cause an associated change in RPE due to the close relationship of these two variables. As with V_e, the introduction of relaxation caused a decreasing trend in RPE compared to a non-significant rise in the control group in trial II as seen in Figure 3. There was a significant main effect for time (F (4,48) = 40.46 $p < .05$). As the duration of exercise increased the perceived exertion of the subjects in each group did as well. The Tukey post-hoc test (Table 9) revealed that min 10, 15, 20, and 25 were significantly greater than min 5, min 20 and 25 were significantly greater than min 10, and min 25 was significantly greater than min 15. This normal increase in RPE during exercise was unaffected by relaxation. No significant main effect was found for group (F (1,12) = .90 $p > .05$) or trial (F (1,12) = .20 $p > .05$). The descriptive statistics for RPE data can be found in Table 10.

Oxygen Consumption Analysis and Descriptive Statistics

There was no significant difference between the relaxation and control groups with respect to VO_2. No significant interactions were found (Table 11) for the interactions of trial x time x group (F (4,48) = .62 $p > .05$), trial x group (F (1,12)

Table 8

RPE ANOVA summary table

Source	SS	df	MS	F	p
Group	23.21	1	23.21	.90	.36
Sw/Group	310.74	12	25.90		
Trial	.58	1	.58	.20	.66
Trial x Group	13.21	1	13.21	4.60	.053
Error (Trial)	34.51	12	2.88		
Time	193.04	4	48.26	40.46	.00*
Time x Group	3.90	4	.98	.82	.52
Error (Time)	57.26	48	1.19		
Trial x Time	.81	4	.20	1.06	.39
Trial x Time x Group	.19	4	.05	.24	.91
Residual	9.20	48	.19		

*Denotes significance at the .05 level.

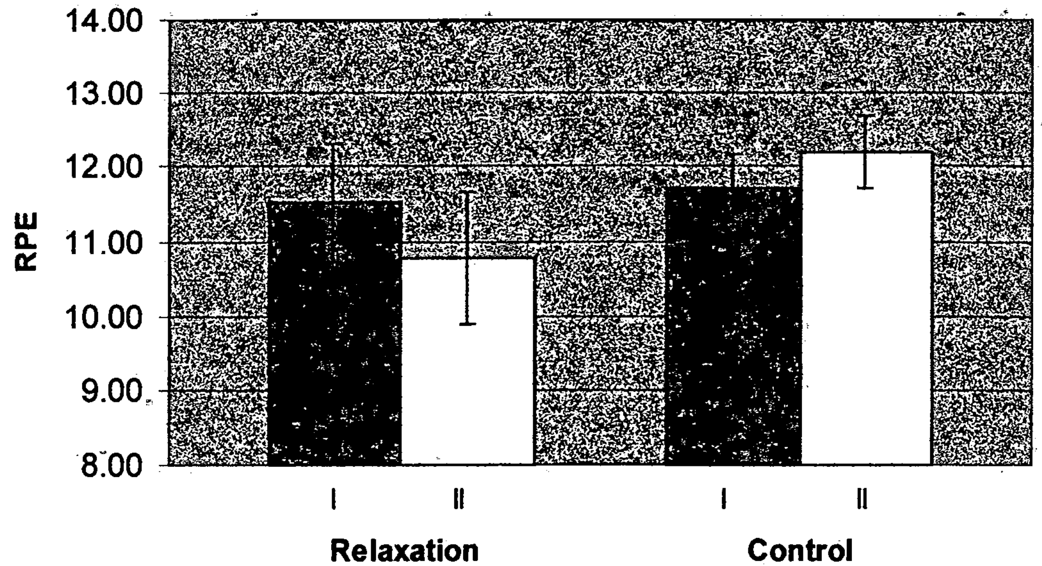

Figure 3. Trial comparison of RPE means +/- SEM for relaxation and control groups.

Table 9

Tukey post-hoc analysis for RPE time main effect

Means		9.72	10.93	11.61	12.39	13.12
	Time	5	10	15	20	25
9.72	5	-	-	-	-	-
10.93	10	1.12*	-	-	-	-
11.61	15	1.89*	.68	-	-	-
12.39	20	2.67*	1.46*	.78	-	-
13.12	25	3.40*	2.19*	1.51*	.73	-

*Denotes significance with a critical difference of .89.

Table 10

Descriptive data for pretest and posttest RPE

Group	Pretest Mean	Pretest SD	Pretest SEM	Posttest Mean	Posttest SD	Posttest SEM
Relaxation (N=7)						
Minute 5	9.29	1.38	.52	8.86	1.68	.63
Minute 10	10.86	1.68	.63	9.86	1.77	.67
Minute 15	11.71	2.29	.87	11	2.24	.85
Minute 20	12.57	2.44	.92	11.71	2.63	.99
Minute 25	13.14	2.73	1.03	12.43	3.31	1.25
Control (N=7)						
Minute 5	10.00	1.41	.53	10.71	1.25	.47
Minute 10	11.29	1.11	.42	11.71	1.38	.52
Minute 15	11.57	1.51	.57	12.14	1.46	.55
Minute 20	12.43	1.13	.43	12.86	1.35	.51
Minute 25	13.29	.95	.36	13.57	1.13	.43

Table 11

VO$_2$ ANOVA summary table

Source	SS	df	MS	F	p
Group	18.27	1	18.27	.19	.67
Sw/Group	1156.77	12	96.40		
Trial	12.24	1	12.24	2.35	.15
Trial x Group	1.81	1	1.81	.35	.57
Error (Trial)	62.53	12	5.21		
Time	57.04	4	14.26	13.85	.00*
Time x Group	3.92	4	.98	.95	.44
Error (Time)	49.42	48	1.03		
Trial x Time	2.40	4	.60	1.09	.37
Trial x Time x Group	1.37	4	.34	.62	.65
Residual	26.33	48	.55		

*Denotes significance at the .05 level.

= .35 $p > .05$), time x group (F (4,48) = .95 $p > .05$), and trial x time (F (4,48) = 1.09 $p > .05$). Drift in VO_2 caused a significant increase over time (F (4,48) = .90 $p < .05$). The Tukey-post hoc analysis (Table 12) revealed that min 15, 20, and 25 were significantly greater than min 5 for both trials of the relaxation and control groups. Also, min 25 was found to be significantly greater than min 10. No significance was found in the main effects for group (F (1,12) = .19 $p > .05$) or trial (F (1,12) = 2.35 $p > .05$). Descriptive data including M, SD, and SEM for VO_2 can be found in Table 13.

Arm Swing Analysis and Descriptive Statistics

The three-way ANOVA for analysis of AS showed no significance for the interaction trial x time x group (F (4,48) = .88 $p > .05$) (Table 14). Significance was found for the two-way interaction of trial x group (F (1,12) = 9.19 $p < .05$). Tukey-post hoc analysis revealed a significant decrease in AS with the introduction of relaxation (Table 15). This interaction is visually presented in Figure 4. No other two-way interactions were found in time x group (F (4,48) = .15 $p > .05$) or trial x time (F (1,12) = .21 $p > .05$). There was a significant main effect shown with trial (F (1,12) = 22.38 $p < .05$) showing that overall AS in trial II was decreased when compared to trial I for both groups. Other main effects including group (F (1,12) = .04 $p > .05$) and time (F (4,48) = .99 $p > .05$) were not statistically significant. Means, SD, and SEM for each subject's AS data can be found in Table 16.

Table 12

Tukey post-hoc analysis for VO_2 time main effect

Means		32.28	33.08	33.32	33.79	34.07
	Time	5	10	15	20	25
32.28	5	-	-	-	-	-
33.08	10	.8	-	-	-	-
33.32	15	1.04*	.24	-	-	-
33.79	20	1.51*	.71	.47	-	-
34.07	25	1.79*	.99*	.75	.29	-

*Denotes significance with a critical difference of .81.

Table 13

VO_2 Descriptive data

Group	Pretest Mean	Pretest SD	Pretest SEM	Posttest Mean	Posttest SD	Posttest SEM
Relaxation (N=7)						
Minute 5	31.34	3.01	1.14	32.15	4.57	1.73
Minute 10	32.91	3.53	1.33	33.10	4.40	1.66
Minute 15	32.33	4.05	1.53	33.43	4.55	1.72
Minute 20	33.07	4.16	1.57	33.90	4.90	1.85
Minute 25	33.20	4.21	1.59	34.36	4.99	1.88
Control (N=7)						
Minute 5	32.41	2.35	.89	33.20	3.69	.99
Minute 10	33.17	1.42	.54	33.12	3.39	.91
Minute 15	33.80	1.51	.57	33.73	3.28	.88
Minute 20	33.93	1.47	.56	34.25	3.46	.93
Minute 25	34.29	1.38	.52	34.41	3.50	.93

Note. Values are in ml/kg/min.

Table 14

Arm swing ANOVA summary table

Source	SS	df	MS	F	p
Group	13.18	1	13.18	.04	.85
Sw/Group	4454.68	12	371.22		
Trial	176.40	1	176.40	22.38	.00*
Trial x Group	72.48	1	72.48	9.19	.01*
Error (Trial)	94.60	12	7.88		
Time	63.06	4	15.76	.99	.42
Time x Group	9.75	4	2.44	.15	.96
Error (Time)	767.91	48	15.99		
Trial x Time	14.96	4	3.74	.21	.93
Trial x Time x Group	62.41	4	15.60	.88	.49
Residual	855.59	48	17.83		

*Denotes significance at the .05 level.

Table 15

Tukey post-hoc analysis for AS trial x group interaction

Means		39.17	35.48	38.34	37.54
	Trial	IR	IIR	IC	IIC
39.17	IR	-	-	-	-
35.48	IIR	3.69*	-	-	-
38.34	IC	.83	2.86*	-	-
37.54	IIC	1.63	2.06*	.80	-

Note. R= relaxation group; C= control group

*Denotes significance with a critical difference of 2.01.

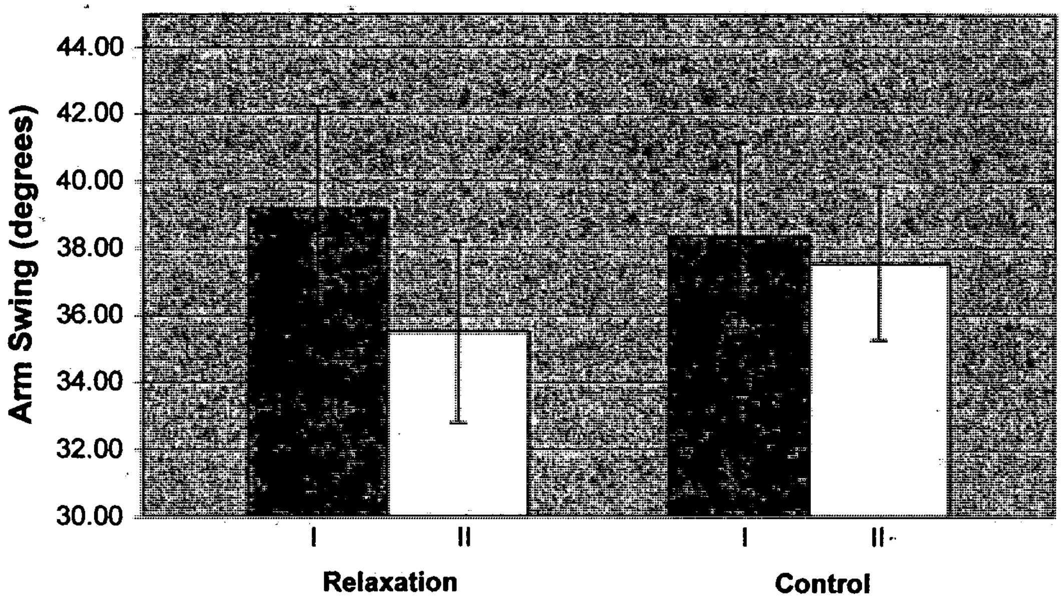

Figure 4. Trial comparison of AS +/- SEM for relaxation and control groups. * = significant decrease from trial I to trial II in the relaxation group.

Table 16

Arm swing descriptive data

Group	Pretest Mean	Pretest SD	Pretest SEM	Posttest Mean	Posttest SD	Posttest SEM
Relaxation (N=7)						
Minute 5	39.78	9.24	3.49	35.91	8.31	3.14
Minute 10	40.56	8.20	3.10	35.57	10.32	3.90
Minute 15	37.99	9.14	3.46	35.49	5.92	2.24
Minute 20	38.20	5.61	3.46	34.25	5.88	2.22
Minute 25	39.31	5.61	1.70	36.20	5.40	2.04
Control (N=7)						
Minute 5	37.64	8.14	3.08	38.12	5.39	2.04
Minute 10	38.28	7.39	2.79	38.98	5.28	1.99
Minute 15	39.89	7.39	2.79	36.79	5.72	2.16
Minute 20	36.01	4.93	1.86	37.11	6.16	2.33
Minute 25	39.89	8.86	3.35	36.68	7.78	2.94

Note. Values are in degrees.

Hip Flexion Analysis and Descriptive Statistics

No significance was found for the ANOVA (Table 17) for HF. No three-way interaction existed in trial x time x group (F (4,48) = .20 p > .05). All two-way interactions were found not to be significant with trial x group = (F (1,12) = 1.21 p > .05), time x group = (F (4,48) = .93 p > .05), and trial x time =(F (4,48) = .44 p > .05). In addition, group main effect (F (1,12) = 3.35 p > .05), trial main effect (F (1,12) = 1.21 p > .05), and time main effect (F (4,48) = 1.11 p > .05) were also not significant. The high activity of the lower extremity appears to have overridden any attempt to impose relaxation. Descriptive data for HF can be found in Table 18.

Step Length Analysis and Descriptive Statistics

Like HF, no significance was found for any of the conditions measured in the 2 x 2 x 5 ANOVA for SL (Table 19). No interactions for SL were found to be significant. These interactions include trial x time x group (F (4,48) = .22 p > .05), trial x group = (F (1,12) = 3.98 p > .05), time x group = (F (4,48) = .90 p > .05), and trial x time =(F (4,48) = 1.53 p > .05). Group main effect (F (1,12) = .07 p > .05), trial main effect (F (1,12) = .16 p > .05), and time main effect (F (4,48) = 1.95 p > .05) were also all not statistically significant. Descriptive data showing the lack of influence of relaxation on SL can be found in Table 20.

Summary

ANOVA results indicated that each of the physiological factors tested (HR, V_e, RPE, VO_2) underwent an expected significant increase over time due to drift with

Table 17

Hip flexion ANOVA summary table

Source	SS	df	MS	F	p
Group	8.82	1	8.82	3.35	.09
Sw/Group	31.55	12	2.63		
Trial	.12	1	.12	1.21	.29
Trial x Group	.00	1	.00	.00	.99
Error (Trial)	1.19	12	.09		
Time	.92	4	.23	1.11	.36
Time x Group	.77	4	.19	.93	.46
Error (Time)	9.92	48	.21		
Trial x Time	.38	4	.09	.44	.78
Trial x Time x Group	.17	4	.04	.20	.94
Residual	10.42	48	.22		

Table 18

Hip flexion descriptive data

Group	Pretest Mean	Pretest SD	Pretest SEM	Posttest Mean	Posttest SD	Posttest SEM
Relaxation (N=7)						
Minute 5	1.96	.78	.29	1.80	.63	.24
Minute 10	1.59	.50	.19	1.57	.53	.20
Minute 15	1.59	.51	.19	1.58	.57	.22
Minute 20	1.62	.48	.18	1.59	.50	.19
Minute 25	1.67	.42	.16	1.59	.45	.17
Control (N=7)						
Minute 5	2.32	.91	.34	2.00	.46	.17
Minute 10	1.97	.71	.27	2.03	.64	.24
Minute 15	2.22	.75	.28	2.26	.82	.31
Minute 20	2.19	.67	.26	1.99	1.03	.39
Minute 25	2.24	.71	.27	2.35	.83	.31

Note. Values are in degrees.

Table 19

Step length ANOVA summary table

Source	SS	df	MS	F	p
Group	20.02	1	20.02	.07	.79
Sw/Group	3353.03	12	279.42		
Trial	.98	1	.98	.16	.70
Trial x Group	24.50	1	24.50	3.98	.07
Error (Trial)	73.89	12	6.16		
Time	23.13	4	5.78	1.95	.12
Time x Group	10.70	4	2.67	.90	.47
Error (Time)	142.20	48	2.96		
Trial x Time	16.40	4	4.10	1.53	.21
Trial x Time x Group	2.38	4	.60	.22	.93
Residual	129.04	48	2.69		

Table 20

Step length descriptive data

Group	Pretest Mean	Pretest SD	Pretest SEM	Posttest Mean	Posttest SD	Posttest SEM
Relaxation (N=7)						
Minute 5	77.35	6.40	2.42	77.18	5.36	2.03
Minute 10	78.88	6.07	2.29	79.03	6.63	2.51
Minute 15	78.35	4.74	1.79	78.28	5.03	1.90
Minute 20	79.58	6.28	2.37	77.59	4.92	1.86
Minute 25	79.61	7.44	2.81	78.35	5.23	1.98
Control (N=7)						
Minute 5	78.04	5.01	1.90	79.74	6.41	2.42
Minute 10	78.12	5.16	1.95	79.65	5.49	2.08
Minute 15	78.90	5.56	2.10	79.66	5.09	1.92
Minute 20	79.16	4.31	1.63	79.10	4.34	1.64
Minute 25	79.15	5.29	1.99	80.24	5.16	1.95

Note. Values are in cm.

prolonged exercise. Relaxation appeared to have no effect on altering this normal progression in the subjects as the drift was consistent throughout both trials

Results of the investigation showed a significant interaction between the groups and trial in the V_e measures. The control group showed a nonsignificant increase in V_e from trial I to trial II while the relaxation group showed a nonsignificant decrease in trial II with the introduction of relaxation. The control group had an overall higher V_e over both trials. While a statistically significant interaction was found, inspection of these data reveal the actual physiological impact of relaxation training on V_e was minimal.

Measurements of V_e and RPE are traditionally very closely related. The analysis of RPE measures showed a similar effect to those found of V_e. While the control group showed a nonsignificant increase from trial I to trial II, the relaxation group showed a nonsignificant decrease or suppression of perceived exertion after the introduction of relaxation. The analysis did not show significance with RPE for group x trial but was very close with a $p = .053$.

Biomechanical data for HF and SL, showed no significant changes in any of the conditions tested. However, relaxation did have an affect on AS measurements with a significant interaction for trial and group. The relaxation group was able to significantly decrease upper arm motion by decreasing AS through relaxation. The control group did show a small decrease in AS from trial I to trial II but this change was not significant.

Chapter 5

DISCUSSION

The focus of this chapter will be to discuss the results of chapter 4 in greater detail. The discussion is presented in the following order: (a) the effects of relaxation on physiological factors of running, (b) the effects of relaxation on biomechanical factors of running, and (c) summary.

The Effects of Relaxation on Physiological Factors of Running

A primary focus of the present investigation was to examine the effects of relaxation on HR during exercise. Theoretically, a decrease in HR during exercise while maintaining the same absolute workload would be beneficial to the long distance runner. The ability to accomplish this goal would allow for more efficient metabolism during exercise and aid in conservation of energy. This in turn would potentially allow for an improvement in performance. A primary effect brought about by relaxation during rest is a decrease in HR (Solberg et al., 1996; Gieremek et al., 1994). This investigation attempted to create this same effect during exercise, while maintaining intensity.

Relaxation is achieved through changes brought about by the autonomic nervous system (ANS). The ANS has direct control over HR during exercise and through a variety of mechanisms allows the heart to adapt to the demands placed on the body. The ability to alter ANS activity through the use of relaxation techniques has direct effects on contractility as well as rate of the heart. The results of this investigation showed that a decrease in HR was not achieved while using relaxation techniques during exercise. The enhanced stimulation and demand on the heart during exercise appears to have overridden any attempt at triggering a relaxation effect. These findings are in agreement with previous investigations examining relaxation interventions during exercise (Boone & DeWeese, 1998; Gervino & Veazey, 1984). These previous investigations reported a decreasing trend in HR with the initiation of relaxation. This trend was evident in the current investigation but, like previous studies, was not significant. Relaxation seems to have a slight effect on HR values but is not strong enough to overcome ANS activity during exercise.

Our findings are also in agreement with Hatfield et al. (1992), who examined the effects of distraction and feedback interventions during exercise. The cardiovascular demand on an individual during exercise appears unalterable as set by the central cardiovascular centers. The importance of the delivery of O_2 to the working muscles during exercise and the maintenance of blood pressure are the primary goals that drive HR. The present results demonstrate that the heart in normal exercise situations, works very efficiently, and is very accurate in controlling cardiac output without excess energy usage. Any inhibitory effect caused by relaxation may be detrimental in maintaining intensity due to the efficiency the cardiovascular system has already attained in trained individuals.

In contrast, Perski et al. (1985) showed that HR is a physiological factor that is able to be altered through the use of biofeedback. They were able to lower the HR of their subjects by 22% in short duration bouts of cycling. Their subjects were tested over 5, 4 min bouts of exercise at 65% of VO_{2max}. The ability to trigger a relaxation response in the Perski et al. examination may have been due to the extensive use of biofeedback. The present investigation only used one bout of biofeedback intervention. A more intensive biofeedback training phase may have been more effective in attaining a stronger relaxation response. Other examiners have found positive results of biofeedback on the relaxation response during running, including Blumenstein et al., (1995) and Caird et al. (1999). Future investigations should take these findings into account and implement extensive biofeedback during exercise.

Emphasis was placed on the design of the present study to allow for a more practical approach than previous investigations. Boone and DeWeese (1998), Hatfield et al. (1992), and Gervino and Veazey (1984) all used protocols where the subjects were required to turn the relaxation response on and off during one testing bout. The design used in the present study allowed relaxation subjects to concentrate on relaxation throughout exercise, rather than turning on and off the relaxation response for certain periods of time throughout the exercise bout. This "flipping of the switch" may have brought about conflicting messages to the ANS, and may have caused the subjects to lose focus on the task. The present approach should have allowed for superior cultivation of the focused and effective attitude needed to trigger the relaxation response. Although this approach was more likely to elicit significant results, and was closer to how an athlete might implement relaxation techniques during long distance events, significance was not reached in the measured variables.

The present study also utilized a control group design in order to monitor normal changes over a 2-week period when two, identical 25 min runs are performed. A common occurrence during prolonged exercise is the tendency for an upward drift in HR as duration increases (McArdle, Katch, & Katch, 1994). The strength of the present design allowed examination of the effect of relaxation on the drift of HR and other physiological factors. The normal HR drift demonstrated in trial I by both groups, however, was not in any way affected by the implementation of relaxation during trial II. Each of the subjects consistently achieved a significant increase from steady state values in HR by min 15 of the exercise bout.

Previous investigations (Caird et al., 1999; Boone and DeWeese, 1998; Benson, 1978) found that the intervention of relaxation during exercise significantly lowered V_e in the subjects tested. The present investigation provided marginal support for these findings, as a significant interaction between the groups was found when relaxation was introduced during exercise. However, neither group reflected a significant change from trial I to trial II and the true physiologic impact of relaxation on V_e appears to be very small. Although V_e is a physiological factor that we have a significant amount of voluntary control over, the ANS plays a large role in regulation of breathing during exercise. Most of the time runners are not focusing on their breathing and rely on the ANS to regulate V_e unconsciously. The ANS has direct effects on the amount of bronchiodilation within the air passages of the lung, therefore controlling how much air is able to freely flow in and out of the lung. Relaxation can produce a withdrawal of this response allowing less air to be brought into the lung with each breath. The introduction of relaxation in the subjects in the present study caused a nonsignificant decreasing trend in the relaxation group while the control group showed a nonsignificant increasing trend from trial I to trial II. Thus very small changes in V_e resulted in a significant interaction. A more intensive relaxation training program, perhaps using biofeedback, may have furthered this trend to the point of stronger agreement with previous work, but this is only speculative.

According to Bailey and Pate (1991), V_e accounts for 7-8% of the O_2 cost of exercise. This is a large percentage of total energy output and any reduction in this energy utilization with maintenance of intensity would be very beneficial to the long distance runner. Ventilatory demand can be limited by decreasing stimulation and work of the respiratory muscles. Boone and DeWeese (1998) reported a drop in frequency of breaths by 10% with the introduction of relaxation during running while VO_2 was maintained. The mechanism for this change is unclear but they attributed the finding to a greater extraction of O_2 at the lungs. This problem led Boone and DeWeese to question the efficacy of VO_2 as the criterion variable for demonstrating changes in RE and further investigation is needed to fully understand this mechanism.

Like Boone and DeWeese (1998), this investigation failed to find any significant change in VO_2 brought about by relaxation. The literature on this physiological finding is split among previous investigators. We are also in agreement with Hatfield et al. (1992) who reported that cognitive interventions have no affect on VO_2 during exercise. Caird et al. (1999) and Gervino & Veazey (1984) were able to demonstrate reduced VO_2 through the use of cognitive interventions in their investigations. Theoretically, a relaxation response can effectively conserve energy by improving the introduction and delivery of O_2 to the working musculature but these previous investigations offer little insight into how relaxation training might cause these effects. Our results do support Williams et al. (1990) and Morgan et al. (1991) in their conclusion that RE is a steady measurement that can be obtained in a single measurement when variables such as accommodation, footwear, and time of day are controlled. Not only was stability demonstrated in the control group but also when an intervention such as relaxation was introduced.

In 1985, Morgan demonstrated a close linear relationship between V_e and RPE. How hard an individual is breathing plays a large role in their perceived exertion during activity. In the present examination, the effects of relaxation on RPE were not found to be significant, but approached significance with a $p = .053$. The RPE results nearly mirrored V_e and showed a decreasing trend in the relaxation group, and an increasing trend in the control group from trial I to trial II. One of the main focuses of the modified

PMR/AT technique used was to concentrate on breathing during exercise. This relaxation method was close to being successful in allowing the subjects to decrease tension, thereby almost decreasing the perceived exertion of exercise. With a greater sample size and more extensive relaxation training, a future study may be able to demonstrate a relaxation effect on RPE values. Such a finding may be beneficial to the runner by increasing tolerance to exercise and improving performance.

One major limitation of this investigation was the time given to effectively learn the relaxation response and incorporate it into exercise. Previous research has shown the importance of the duration of relaxation training, demonstrating that the longer relaxation is practiced the more effective it becomes (Gieremek et al., 1994; Lichstein, 1988). This statement was derived from learning relaxation techniques and incorporating them while at rest. The learning curve for relaxation that comes along with incorporating it into exercise would be expected to be longer. It is questionable if two weeks is adequate time to effectively learn relaxation at rest, let alone be able to incorporate it during a high nervous system activity such as exercise. Future research should focus on an extended relaxation training phase with more emphasis placed on incorporating the technique into exercise. Incorporation of relaxation into exercise was more directly addressed in the present study compared to previous research, but still appears to have been insufficient. Martin, Craib, and Mitchell (1995) demonstrated that more economical runners habitually direct attention more inward than less economical runners. A longer, more focused relaxation training phase will help to cultivate such an attitude and may improve effectiveness. Future research should also consider exploring different relaxation techniques. Techniques that emphasize cognitive methods may be more effective during activity because PMR may be difficult to implement during intense muscular activity.

Benson (1975) explained four primary characteristics needed in order for relaxation to be as effective as possible. The attempt to incorporate relaxation into the exercise situation makes it very difficult to adhere to Benson's recommendations. These recommendations include a mental device, quiet environment, comfortable position, and a passive attitude. The only one of these characteristics that was completely adhered to was the mental device. Other characteristics such as a quiet environment and a comfortable position were impossible to achieve in the exercise situation. In addition, a passive attitude would also be very difficult to accomplish during exercise at 75% of maximum capacity. This may have affected the ability of the subjects to trigger or maintain a relaxation response. As a result, any attempt to alter physiological or biomechanical responses to exercise would not likely be successful.

Caird et al. (1999) utilized a much more extensive intervention phase in their examination. Ideally, we would have liked to implement a more intensive relaxation training program but were unable to do so because of time constraints. They employed a six-week relaxation training phase, which allowed their subjects to become more familiar with the relaxation response than the subjects of this investigation. Caird et al.'s study only took initial steady state measures that may have dramatically limited their findings. The ability to monitor the effects of extensive relaxation training on the physiological drift during exercise was sacrificed due to this decision. The present study was unable to demonstrate any impact of relaxation training on physiological drift during exercise.

The role relaxation plays on physiology during running continues to elude a complete and accurate answer. Promising trends in V_e and RPE were found in the present study to support the improvement of running efficiency, but the strength of these data are not great and require confirmation by future study. While we are in agreement with various authors, we are also in conflict with others. Many problems were addressed in the present study, but many others were uncovered. Future research should focus on biofeedback playing a larger role in a more extensive relaxation training phase. Biofeedback, incorporated with the more functional design used in the present investigation, would be the best way to determine the effectiveness of relaxation on physiological factors.

The Effects of Relaxation on Biomechanical Factors of Running

Previous literature has not addressed the effects of relaxation on the biomechanical factors of running. This is the first investigation to look at this concept and therefore take a more complete look at the potential effects of relaxation on running efficiency. Cavanagh and Williams (1982) believed that 54% of variation in RE could be attributed to variation among different biomechanical variables. This examination attempted to take this consideration into account and investigate if relaxation played a direct role in altering the biomechanics of running. Certain biomechanical variables are suggested to play a larger role than others in the determination of RE (Morgan et al., 1989). This investigation selected those variables (i.e., AS, HF, and SL) that are expected to play a large role in determining running efficiency.

The results showed that HF and SL were not affected by the introduction of relaxation. HF and SL are closely related, as a change in the length of one step will bring a corresponding change in the angle at the hip and vise versa. An increased economy has been associated with an increased maximal hip extension according to Cavanagh and Williams (1982). No change was seen in hip ROM throughout this study as stride mechanics were stable for all subjects. This finding does not solve the problem presented by Cavanagh and Williams (1982) and Bailey and Messier (1991). These investigators suggested that stride length adapts either through training or changes in an attempt to reduce RPE. This issue needs to be more specifically addressed and is out of the scope of this study. The lower extremities are working at such a high intensity, at 75% of maximum capacity, that relaxation effects on the ANS may be overridden by the great metabolic needs of the active muscles.

In contrast to the lower extremity, the upper extremity is less active during running. This level muscle activity may allow alterations of the sympathetic nervous system (SNS) through relaxation to be possible in the musculature of this area. Daniels (1985) believed that eliminating counter productive muscular movement helps to maximize efficiency. This concept was supported by Cavanaugh and Kram (1985) who found that a decrease in AS is associated with an increase in economy. Gervino and Veazey (1984) found that the upper body is more relaxed in more economical runners. These more experienced runners are able to use energy more efficiently causing improved performance. The PMR/AT technique of the present investigation appears to have been effective in allowing the subjects to recognize unneeded tension in the upper body and help decrease that tension. Relaxation resulted in a significant decrease in AS during running. This decrease in excessive movement may have allowed a decrease in upper body energy usage for the relaxation subjects thereby allowing greater energy utilization by the legs. This proposed reduction in upper body energy usage, however, was not found to enhance the overall efficiency of the subjects in this study as measured by VO_2.

The effects of relaxation on the biomechanics of running appear to be minimal at best. Although subjects showed a significant decrease in AS with the introduction of relaxation, no improvement in overall efficiency was seen. The small amount of energy conserved with these changes was likely too insignificant to impact performance. Lower extremity biomechanics appear to adapt to optimal levels through training. The two-week relaxation program used in the present study had no effect on the high intensity muscular work of the legs. Limitations of the present study prevented a more thorough and complete examination of running biomechanics. Once again the limited amount of relaxation training may have restricted the findings as well.

Summary

The findings of this investigation showed that relaxation has a minimal effect on the improvement of RE in moderately trained female runners. All physiological factors examined (HR, V_e, VO_2, RPE) had minor or no significant changes with the introduction of relaxation during running. Normal upward drift over time of these factors was maintained and little differences were noted when the relaxation response was initiated. Several factors did show an encouraging trend, as found in previous investigations, which leads to the possibility that length of the relaxation training protocol in this study was too short. The cardiovascular system appears to be a very persistent controller of cardiac output and a longer, more intense relaxation protocol that focused more on biofeedback may have been required to have an impact on the physiological factors measured.

Compared to previous investigations, the design used in the present study appears to be a more practical way to measure the affects of relaxation during exercise. The subjects are able to more completely focus on obtaining relaxation instead of getting distracted by turning the relaxation response on and off. This investigation also incorporated a control group in order to monitor the normal upward drift of each physiological measurement and allow for examination into the role relaxation plays on this drift. Future research should take these design factors into consideration.

To date, this investigation is the only investigation that looks at relaxation's affect on the biomechanical aspects of running. This allowed us to take a more complete look at running efficiency and see where any changes in performance caused by relaxation could be found. The modified PMR/AT technique used was successful in decreasing excess muscle activation in the upper body by decreasing AS. This may be beneficial to longer distance runners since a decrease in AS has been associated with a greater RE (Cavanaugh & Williams, 1982; Gervino & Veazey, 1984). Lower extremity mechanics were unaffected by relaxation. The body may already be performing at the most efficient level and any impact of relaxation on lower body mechanics may be detrimental to performance.

Overall, the examination of the effects of relaxation on running efficiency has many questions that remained unanswered. This investigation and earlier work are divided and point to this topic as needing further, more in depth evaluation. Incorporating a more intensive relaxation intervention appears to be the biggest problem, as the learning curve to implement a relaxation technique into exercise is much longer than at rest. Future investigations should look toward achieving agreement of previous investigations by taking into consideration the problems raised in this investigation.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This investigation examined the effects of relaxation on the running efficiency of moderately trained individuals. Fourteen moderately trained female runners were examined in the study. The subjects were divided into a control group and a relaxation group. Each group completed two trials of testing at 75% of their measured maximal VO_2. The trials were separated by two weeks during which the relaxation group received PMR/AT practice and the control group monitored their normal weekly exercise schedule. Both physiological (HR, V_e, VO_2, RPE) and biomechanical (AS, HF, SL) factors were measured every five minutes in each trial.

A 2 X 2 X 5 ANOVA was used to analyze all data with significant differences further investigated by the use of Tukey's post-hoc analysis. It was determined that no important physiological changes were caused by the introduction of relaxation training. Further, the normal physiological drift in each of these factors was unaffected by relaxation training. RPE and V_e did show encouraging trends for a potential improvement of efficiency but the effects were too small to achieve significance. A longer, more intensive relaxation training program may have allowed relaxation to have a greater effect on the physiological factors measured.

The lower extremity biomechanical factors measured were also unaffected with the introduction of relaxation. HF and SL were unchanged possibly due to the inability to trigger a relaxation response over the high metabolism demanded by the musculature of the lower extremities during running. Relaxation appeared to be effective in the upper extremity musculature causing a decrease in the AS of the relaxation group. Although excessive energy usage may have decreased, the energy conserved by this change was apparently too small to cause any improvement in overall efficiency of the subjects.

Conclusions

The results of this study yielded the following conclusions regarding the effect of relaxation on running efficiency in moderately trained females.

1. Relaxation has no substantial positive effect on altering the physiological markers of running efficiency however encouraging trends in RPE and V_e should be further investigated.

2. Relaxation does appear to be effective in decreasing excess muscular activation in the upper extremities.

3. Lower extremity metabolism and biomechanics during running appears to be unaffected by attempts to improve their efficiency through relaxation.

4. Running economy is a stable measurement and a reliable measure can be obtained from one testing bout.

Recommendations

Based on the findings of this investigation the following recommendations are made for future researchers.

1. Incorporate a longer, more intensive relaxation training program that places more emphasis on learning the relaxation technique during exercise.

2. Utilize the benefits of biofeedback more during the relaxation training phase in order to more effectively learn how to trigger the relaxation response.

3. Use a similar design as the one used in this investigation where subjects focus on inducing relaxation for the duration of exercise. This will allow for less confusion in the cardiovascular centers of the brain as there is no conflicting messages from turning the relaxation response on and off. This approach makes the technique more practical and useful for the long distance runner.

4. The role relaxation plays in the biomechanics of running needs to be investigated more thoroughly. A more specific look at all joint angles should be examined in order to examine all possible changes in running mechanics.

5. Different relaxation techniques should be examined in order to determine if any one is most effective during exercise.

Subjects Needed for a Running Study on the Effects of Relaxation and Training Habits

Trained sub elite runners are needed in order to study the effects of relaxation or training habits on running efficiency (performance). A trained sub elite runner is defined as a runner with at least three years experience running at an average of three times a week for 20 minutes.

What you get:

- Your VO_{2max} - the best measure of aerobic fitness
- Biomechanical analysis of your running style
- Relaxation Group- A relaxation technique which may improve performance and can be used in all facets of life to decrease stress
- Training Habit Group- How exercising the day before an event will effect your performance

What you will be required to do:

- Maximum exercise test
- Three, 25 minute treadmill runs
- Relaxation Group- 2 weeks of home relaxation training
- Training Habit Group- Keep an exercise log for 2 weeks of your exercise habits
- Both groups report for a total of 6 testing or instruction sessions

For more information please contact Jim Reidy at 277-6259 or through e-mail at JReidy2829@aol.com

Appendix B

Informed Consent Form

Purpose of the Study: The purpose of the present study is to examine if relaxation or training habits improve running efficiency and subsequently performance.

Benefits of the Study: By participating in this study you will learn what your maximum aerobic power output and running economy are, which will enable you maximize your training program. Also any biomechanical differences that produce an improvement in your running efficiency will be discovered. The use of relaxation during exercise may allow individuals to improve performance.

What You will be Asked to Do: You will report to the laboratory for 6 sessions. Session 1 will consist of a treadmill accommodation run in order to get use to the oversized treadmill that will be used throughout the study. You will run for 20 minutes to get a feel for the treadmill as well as the other equipment to be used (gas analyzer, BP cuff). Session 2 will consist of a maximum aerobic power output test in order so we can set your testing intensity at 75% of your max. This test will consist of running on the oversized treadmill while breathing gases are being monitored until volitional exhaustion. Headgear holding a device to your mouth will be used to measure expired gases. In session 3 you will run for 25 minutes at 75% of your measured maximum oxygen uptake and be measured every five minutes for a variety of factors. One of these factors includes biomechanical analysis where you will be videotaped for 15 seconds every 5 minutes. The other measurements will include blood pressure with the use of a blood pressure cuff and physiological measures derived from the gas analyzer. Subjects will then be divided into a relaxation group and a training habits group, which will each come to the lab twice over a two week period (Sessions 4 and 5). The relaxation group will learn a combination relaxation technique consisting of progressive muscular relaxation and autogenic training. The first week of training will occur at rest and the second week of training will occur during exercise. You will meet with me for 30 minutes at the beginning of each week to practice the relaxation technique. The training habits group will keep a training log and will be tested twice for the effects of exercising the day before the test day. The final session (6) will consist of the same 25 min, 75% of max run as before but the relaxation response will be elicited in the relaxation group.

Risks of Participation: The risks of participation are little due to the fact that the testing protocols closely resemble normal training programs.

If Your Would Like More Information About The Study: Please feel free to contact Jim Reidy 277-6259 at anytime prior to, during, or following the data collection.

Withdrawal from the study: All subjects are free to withdrawal from the study at anytime throughout it duration. Please contact Jim Reidy if you decide to withdraw.

Confidentiality: All data collected in the present study will be protected to insure your confidentiality. Your name will not appear in any reports of the results of this study.

I have read the above and I understand its contents. I agree to participate in the study. I acknowledge that I am 18 years of age or older.

____
Print Name

______________________________ _______________
Signature Date

I agree to allow myself to be videotaped in order for biomechanical measurements to be made. Videotapes will be destroyed at the conclusion of the study.

____
Print Name

______________________________ _______________
Signature Date

Appendix C

Subject Questionaire

Name:______________________ Age:_______________

Do you have any current or recent medical problems? (please list)

Are you currently on any medication? (please list)

How many years have you been running? _________

How often per week do you usually run? _________

How long is your average workout? ________

What distance do you usually run during training? _________

Do you train more on a treadmill or outdoors? ____________________

Do you compete in any sports/running competitions? If so which events do you run?

Would you describe yourself as a stressed individual (circle one)?

Yes No

In what ways do you deal with stress?

Have you had any prior experience with the use of relaxation techniques (i.e. autogenic training (AT), progressive muscular relaxation (PMR), yoga, meditation, etc.). ? If so, how much?

Appendix D

Modified Progressive Muscular Relaxation (PMR) and Autogenic Training (AT)

Overview

The relaxation technique will consist of a combination of PMR and AT and will be utilized while you are running. The PMR component will consist of alternately contracting and relaxing various upper body muscles and will last approximately 2 minutes. The AT component will consist of repeating phrases which will help to further elicit the relaxation response. These phrases will be repeated for the duration of running. The technique should be practiced 20 minutes a day, preferably before bed.

PMR Component

Throughout the tensing and relaxing phases, it is most important to focus all of your attention on the sensations coming from your muscles. Compare in your mind the feelings of tension and the relaxation that is emerging. Focus on eliminating the tension in your muscles. The tensing phase should last 5 seconds followed by 10-15 seconds of relaxation.

1.) Tense the muscles of your right hand and forearm by clenching your fist. Relax completely.
2.) Tense the muscles in your right upper arm, the biceps. Relax
3.) Tense the muscles of your left hand and forearm by clenching your fist. Relax.
4.) Tense the muscles of your left biceps in the same manner that you did your right. Relax.
5.) Tense the muscles of your forehead by raising your eyebrows and wrinkling your forehead. Relax.
6.) Tense the muscles of your chest and abdomen concentrate on the tension. Relax.

AT Component

By repeating the following phrases and focusing your attention more on your bodily responses, the relaxation state is more easily attained. Attempt to bring these responses more under voluntary control.

1.) Cardiac regulation: "My heartbeat is calm and regular… My arms are heavy and warm".
2.) Respiration: "My breathing is calm"
3.) Abdominal warmth: "My abdomen is warm"

Continue repeating these phrases and concentrate on releasing the tension in these areas. If your mind strays bring it back slowly and focus on the technique. Allow the relaxation to take place.

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